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Fluidised bed article coating system - with the bed level raised to coat articles

Articles are coated with powdered material by placing them in the upper part of a container (11) above the level of a bed (10) of powdered material fluidised by an ascending stream of gas. The upper part (13) of the container is closed and the level of the bed raised to immerse the article, then lowered and excess powder blown from the article and drawn from the container by suction to be fed to a dust collector (19) from which the powder is fed to a second fluidised bed (20), which supplies fluidised material to the first fluidised bed.

USE
Applying a coating of ground insulation to magnetic cores for dynamo electric machines.

ADVANTAGE
Provides a good even covering over the whole surface of the articles including the corners.

PREFERRED EMBODIMENT
A machine stator is clamped between the upper and

A11-B5A, A12-E8.
lower portions of the container (12, 13) with parts of the i
terior of the stator protected by mask (17). The powder
from bed (20) is fed to the bed (10) via a third fluidised b
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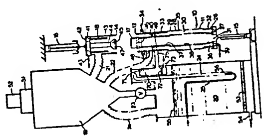

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(21) APPLICATION No. 135,908
(22) FILED Mar. 1, 1972

(30) PRIORITY DATE

No. OF CLAIMS 7

This invention relates to the coating of articles by means of a fluidized bed, and in particular to a system employing a fluidized bed for applying ground insulation to magnetic cores used in electromagnetic devices.

The so-called fluidized bed is now well known in industry for coating articles with protective coatings. It consists essentially of a bed in which a heat diffusible powdered material is held in a fluid-like suspension by means of an ascending current of a diffused gas. If an aritcle is heated above the diffusion temperature of the powdered material and then immersed in the fluidized material, material coming into contact with its hot surface will melt and flow over the surface. Usually, the material is of a type cured by heat, initially by the heat in the article followed by a post cure.

Many variations of the fluidized bed process have been employed for applying a coating of ground insulation to magnetic cores for dynamoelectric machines, for example, stator cores for small AC induction motors. Some of the techniques employed have produced good coatings on the surfaces inside the slots, but have not been equally successful in coating outside corners of the teeth at the ends of the core where the insulation is needed most. The coating on outside corners has been somewhat thinner than that on flat and curved surfaces. Therefore, in order to provide an adequate coating on corners, the coating elsewhere needs to be thicker than necessary. Overly thick ground coatings on slot walls takes up space which would otherwise be taken up by conductors, and it also leads to an excessive use of the powdered insulating material. Both are to be avoided if possible because one tends to increas the physical size of the machine and both incr ase its cost.

The applicant's copending application for Canadian patent, Serial No. 135,907, (Case 2176), Ferguson, filed MARCH 1, 1972, discloses and claims a fluidized bed method and apparatus for coating articles, and in particular for applying ground insulation to magnetic cores. The coatings obtained provide surface coverage as good or better than the conventional coatings, but of better corner coverage. This invention is directed to a system employing the apparatus of the aforementioned application.

A system according to the invention consists essentially of a first bed for fluidizing a quantity of a heat diffusible powdered material to a normal level by means of an ascending stream of a diffused gas; a container for containing the fluidized material and some space above its normal fluid level; means for supporting an article in this space; means for opening and closing the container above the normal fluid level of the bed for inserting or removing the article; means for intermittently raising the level of the fluidized material above the article; means for blowing excess powdered material off the article following a rise of powdered material level; a source of suction connected to the container above the normal fluid level of the bed for exhausting stray gas carried powdered material from around the article; a dust collector operative in the source of suction for collecting said stray powdered material; a second bed for fluidizing another quantity of the powdered material by means of a diffused ascending stream of the same type of gas; means for feeding powdered material from the dust collector to the second fluidized bed; and means for f eding fluidized material from the second bed to the first bed at a controlled rate.

A specific embodiment of the invention will now

be described in some detail with reference to the accompanying drawings, in which

FIGURE 1 is a diagram of a system according to the invention;

FIGURE 2 is a view in cross section of a stator core mounted in the coating apparatus included in the system of Figure 1;

FIGURE 3 is a section taken on plane A-A of FIGURE 2; and

FIGURE 4 is a perspective view of a core coated by means of the system shown in Figure 1.

Figure 1 illustrates a fluidized bed system for applying a coating of ground insulation on a magnetic core for a FHP induction motor. The coating apparatus of this system consists essentially of a fluidized bed 10 movable vertically and contained by an enclosure 11 having its upper end 12 fixed in position and adapted for supporting the core, an upper enclosure 13 movable vertically and having its lower end 14 adapted for fitting down onto the core so that the stack of core laminations is clamped between the enclosures, a linear actuator 15 for raising and lowering bed 10, another linear actuator 16 for lowering and raising upper enclosure 13, a gas mask 17 located in the bore of the core for keeping the bore faces of the teeth free from powder, and a number of gas jets 18 located in the upper enclosure for blowing excess unfused powdered material off the upper end of the core. Figure 1 shows the coating apparatus in its open position ready to receive a core. Please refer to Figure 2 for a detail view of the core identified at 50 in place on the mask and betwe n the two enclosures.

In addition to the apparatus just described, the system also includes a means for exhausting stray gas carried powder from the enclosures, collecting this powd r and

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feeding it back to the fluidized bed for re-use. These components may comprise a dust collector 19 and two additional fluidized beds 20 and ~~770~~ 70. The dust collector, a cyclone separator for example, sucks gas carried powder from the enclosures by way of ducts 21, 22 and 74, consolidates the powder by removing the gas from it, and a feed means 23 despatches the consolidated powder to the large fluidized bed 20. Besides recovering powder from the dust collector, replacement powder is added to the large fluidized bed 20 when required. Powder is fed to fluidized bed 10 from an intermediate fluidized bed 70 which in turn is kept filled to a constant height from fluidized bed 20. The means of transferring powder from fluidized beds 20 to 70 can be a tube 24 which provides a fluid flow passage from bed 20 to bed 70 and a gas jet from a tube 25 which drives the fluidized material from bed 20 through tube 24 to bed 70. Bed 10 is fed powder from bed 70 by way of a duct 75. It is to be noted that bed 70 is at a higher elevation than bed 10. When a normally closed valve 49 in duct 75 is opened, gravity causes fluidized powder to flow through duct 75 from bed 70 to bed 10, bringing bed 10 up to its normal level 40 of fluidization. The gas used in the beds, mask and jets may be dry air, and the linear actuators may be air cylinders energized from the same air supply.

Bed 10 is a conventional type of fluidized bed except for its configuration. It consists of a porous annular diffuser 26 which is connected on its underside to an annular manifold 27 and along the edges of its upper side to two coaxial tubes 28 and 29 respectively referred to as enclosure 11. Tubes 28 and 29 are spaced apart radially so as to define an annular fluidized material space 30 between them of about the same shape as the slotted end of the core

and the diffuser. As a result the bed structure has a hollow centre 31. It is to be noted that the word "annular" as used to described the bed and its enclosure is not restricted to circular shapes; the shape may be other than circular depending on the core. The outer tube has a lower rigid portion 32 secured to diffuser 26 and an upper rigid portion 33 held stationary by a fixed structure 34, and the two rigid portions 32 and 33 are interconnected by means of a flexible bellows 35. Similarly, the inner tube has a lower rigid portion 36 secured to diffuser 26 and an upper rigid portion 37 held stationary by a fixed structure located in hollow 31, and the two rigid portions 36 and 37 are interconnected by means of a flexible bellows 38. The structure for supporting tube portion 37 is not illustrated in the interest of drawing simplicity. The assembly of diffuser 26, manifold 27 and tubular portions 32 and 36 is supported in such a way that it can be raised or lowered by means of actuator 15, bellows 35 and 38 flexing to permit such movement. When a gas such as air is applied in manifold 27 by way of an inlet tube 39 and at a pressure above atmospheric pressure, it becomes diffused in passing through diffuser 26. As the diffused gas ascends in space 30, it carries powdered material with it and holds this material in suspension to form what is now well known as a fluidized bed. The material is fluidized to A a normal level 40 ~~womewhere~~ somewhere below the upper end 12 of the enclosure, e.g., to a level about four inches below end 12. This level can be raised well above mask 17 by raising the lower portion of the bed, i.e., that portion of bed 10 comprising diffuser 26, tubes 32 and 36, manifold 27, and tube 39. As already mentioned the powdered material for bed 10 is obtained from bed 70.

The jets 18 in the upper enclosure 13 consist of a

number of equally spaced tubes projecting downward from an annular manifold 41 which is attached to the upper wall 42 of the enclosure and is supplied with gas by way of a feed tube 43. The jets may have a direction other than downward; they must, however, be directed to sweep a surface of the article being coated. A hollow strut 44 inside the enclosure projects downward from wall 42 coaxial with respect to mask 17. The upper end of the strut is attached to the wall and the lower end carries a cap 45 for mask 17. Wall 42 of the enclosure is attached to the movable member of linear actuator 16 so that the entire enclosure assembly can be moved down and back up by the actuator. Tubes 21 and 43 have flexible portions permitting such movement.

The core 50 to have its slot surfaces coated is placed over the fluidized bed 10 with its bore receiving mask 17 and an outer edge portion of one end of the stack resting on end 12 of enclosure 11. Actuator 16 then lowers enclosure 13 until its end 14 engages the outer edge portion of the other end of the stack. Moreover, flanges 46 and 47 on mask 17 and cap 45 respectively now engage the teeth at the bore of the core. Hence the stack of core laminations is now compressed between the enclosure edges and the flanges. The core is shown in place for coating in Figure 2 along with particulars on the mask itself. These features will be described in more detail later.

Powdered material collector 19 is connected to the upper end of enclosure 13 by way of duct 21 so as to continually apply suction in the enclosure. When the enclosure is in its lowermost position and a core is in the process of being coated, the suction draws off the powdered material blown off the core following each immersion thereof. It is set low enough that it does not disturb the bed when raised

to immerse the core. The collector is also connected to enclosure 11 between mask 17 and the normal fluid level 40 of the bed 10 by way of duct 22. Duct 22 contains a valve 48 which is closed during the coating cycle, but on the completion of each coating cycle immediately following the return of bed 10 to its normal level 40 it is opened. Therefore, following the completion of coating a core and just before raising enclosure 13 to remove the coated core, the region around the core and mask is cleared of stray powdered material. The suction applied via duct 22 is low enough that it does not disturb bed 10 when at its normal level.

Collector 19 is shown as a cyclone separator having an exhaust fan 51 which draws air from the separator tank and exhausts powder free air to the atmosphere via outlet 52. Powdered material separated from the air and collected in the bottom of the tank is fed to the fluidized bed 20 by way of feed means 23. Means 23 may be a motorized valve of a type which feeds powdered material to bed 20 at a measured rate without exposing the bed to the suction in the separator tank. This powdered material along with some make-up material determined by the coating usage in bed 10 provides the feed for bed 20.

Bed 20 is a conventional fluidized bed consisting of a closed container except for a vent to the collector. It is provided with a porous member 53 near the bottom of the container and an inlet 54 admitting a gas such as air into the space below the member. As the gas is at a pressure above atmospheric pressure, it is forced through the porous member and thereby diffused. The diffused gas rises slowly in the container and in so doing, it holds the powdered material in suspension to a level 55.

The intermediate bed 70 is similar to bed 20 except

it is much smaller. It is located inside bed 20 above fluid level 55, and it has a diffuser 72, a gas inlet 73, an open top, and a duct 75 connecting its fluidized zone to the fluidized zone of bed 10 just below level 40. Fluidized material is continually fed from bed 20 to bed 70 by means of a pressurized gas such as air introduced into the upper end of tube 25. This gas escapes from the lower reversely bent end 56 of tube 25, and because it is at a pressure a little above the pressure in the beds, it flows up in tube 24 carrying fluidized material with it to bed 70, entering the bed through its open top. Because the feed to bed 70 is in excess of the requirements for bed 10 and bed 70 is fluidized to a level 71 at its top, some fluidized material spills over the top of bed 70, returning to bed 20.

Duct 75 contains a valve 49 which is closed except for those brief intervals when it is opened to feed fluidized material from bed 70 to bed 10 as make-up for the material lost in the latter for coating purposes. This make-up of material in bed 10 usually takes place immediately after a new core has been placed in the apparatus and just before a new coating cycle is about to begin. During the time that valve 49 is open valve 48 will be closed and fluidized material flows from bed 70 into bed 10 due to gravity because bed 70 is fluidized to a higher level.

Reference should now be made to Figures 2 and 3 where a stator core for an FHP motor is shown mounted in the apparatus ready for coating. It is to be noted that the stack of laminations comprising core 50 is compressed at its outer edge between enclosures 11 and 13 and at its inner dge between flanges 46 and 47 of mask 17 and cap 45 respectively. Hence the laminations are held firmly in a stack while the walls of the slots and the ends of the core are coated, and once coated,

the coating holds the laminations in this way because the coating is continuous and adheres to the edges of the teeth. The core has an outer yoke 57, a plurality of teeth 58 projecting inward from the yoke, and a plurality of slots 59 opening into the bore of the core at 60.

The mask 17 shown in Figures 2 and 3 has a tubular wall 62, a bottom wall 63, a top wall 64, and flange 46 projects outward from the tubular wall at the bottom wall. It is supported on the upper end of the rigid tubular portion 37 of enclosure 11, which portion in turn is supported on structure extending from a stationary base up through hollow 31 of bed 10. When the core is in place for coating as shown in these figures, the mask is located inside the bore of the core with its tubular wall 62 coaxial with respect to and spaced slightly from bore surfaces 61 on the teeth as indicated at 65, and cap 45 is bearing against the upper end of the tubular wall. When the mask and cap are so located, flanges 46 and 47 bear against the tips of the teeth and enclosures 11 and 13 against the outer edge of the core, whereby the laminations are compressed into a compact stack while coating takes place.

The outer surface of the tubular wall is formed with a wedge or tooth 66 for each slot. These wedges project radially and axially from the wall into the slot openings, in which they fit rather snugly. Typically, the space 65 between the wall and the bore surfaces will be about 0.005" and the wedges will project about 0.040" from the wall. Wall 62 contains a row of small holes 67 facing the bore surface 61 of each tooth 58 at the middle thereof, or in place of the rows of holes narrow slits in the wall. A gas at a low pressure is admitted to the hollow in the mask by way of inlet 68. This gas scapes through holes 67 into the spaces

65 between the mask wall and the teeth, then flows along the laminations of the teeth to wedges 66, and finally finds its way past the wedges into the slots. The fit of the wedges in the slot openings is just tight enough and the gas pressure low enough, e.g., about 2 psi, that the gas flows very slowly into the slots. This flow is slow enough that it does not disturb the fluidized material in the slots and yet sufficient to keep the bore surfaces of the teeth and their slot opening edges free from the powdered material. The gas used will be the same kind that is used in the fluidized beds, e.g. dry air.

Because the core is hot when it is in the coating apparatus, heat will be transferred from it to those parts of the apparatus coming into contact with it. Therefore, to prevent a build-up of coating material on these parts, they are cooled by refrigeration. The heat accumulating parts of the apparatus are provided with passages through which a refrigerated liquid is circulated. These passages are located where the liquid coolant can readily extract the heat from the parts. The coolant coils illustrated at 69 in Figure 2 are an example of one method of cooling the mask. These coils are attached to the inner surface of wall 62 in good heat transfer relation therewith in locations where the coolant flowing through them cools the mask. The coolant may be glycol fed to the coils by means of pipes running through hollow 31 from an external refrigerator. These pipes as well as the gas pipes running to the mask are out of contact with the fluidized material. Cap 45 is cooled in the same way by a coolant flowing through ducts in the cap. The coolant is fed to these ducts by means of pipes from the refrigerator running through the hollow of strut 44. Although not shown in Figure 2, enclosures 11 and 13 will

also be cooled at their respective ends 12 and 14 where they come into contact with the hot core.

The method of coating a core by means of the apparatus will now be considered. During coating the following pieces of equipment are in continuous operation; bed 10 is fluidized to its normal level 40; beds 20 and 70 are fully fluidized; collector 19 is in operation; feed means 23 is in operation; and the gas and coolant supplies are in full operation. At this particular stage, there is no core in the apparatus, valve 48 is open and valve 49 is closed. Valve 49 is now opened long enough for powder to flow from fluidized bed 70 into fluidized bed 10 to bring it up to normal level 40. This is a timed sequence and in practice, slightly more than the ideal quantity is allowed to flow into bed 10 and any excess is drawn off through valve 48 which is open at this time. This provides an automatic level control at 40. Valves 48 stays open until the next coating cycle thereby keeping any stray powder off the gas mask 17. Valves 48 and 49 remain closed during the actual coating cycle, ie., during the time that bed 10 is being raised and lowered.

Beginning with the unloaded apparatus shown in Figure 1, a hot core is placed over the mask. This is done by holding the core with its bore vertical and its slot openings in register with wedges 66, and then lowering it over the mask until it rests on edge 12 of enclosure 11 and flange 46 of the mask. The upper enclosure is then lowered until its end 14 bears firmly against the outer edge of the core and flange 47 of cap 45 against the upper end edge of the mask and the inner edge of the core. The loaded apparatus is shown in Figure 2. A hot core is one heated prior to loading in the apparatus to a temperature high enough to

cause the powdered material coming into contact with its surface to melt and flow over the surface.

Next, the fluidized bed 10 is raised so that the fluidized material passes up through the slots of the core to a level above the core and thereby completely envelopes those core surfaces exposed to the bed. Powdered material making contact with the hot surfaces of the core begins to melt and flow over the surfaces. After a short period of time in the order of one second, the bed is lowered to its normal level 40. At the time that the bed is being lowered or immediately after lowering thereof the excess powdered material that has spilled over onto the top surfaces of the core and has lost its fluidity is blown off these surfaces by the jets of gas 18 and exhausted to collector 19 via duct 21. Jets 18 are turned off except for the short spurt following lowering of the bed. Collector 19 continually applies suction to the upper portion of enclosure 13 so that the blown powder or any other stray powder is quickly removed. The sequence of coating steps of raising the bed, lowering the bed and blowing off excess powder is repeated a number of times, e.g., two or three times, until the desired coating thickness is obtained. A number of brief exposures to the fluidized material leads to a more uniform and smoother coating than a single longer exposure. The short exposures allow the material, particularly in th slots, to melt and flow uniformly as heat is released from the core.

Since the coating on the bottom surface of the core tends to build up at a lower rate and less uniformly than it does in the slots, an additional cycle is added to the procedure outlined in the previous paragraph. This additional cycle consists of raising the fluidized bed until its level contacts the lower surface only of the core, holding it at this level for

about a second, and then lowering it again to its normal level. This particular cycle gives better results and is more easily controlled if it is made the first cycle in the coating operation.

Once the core has been coated with the required number of coats of the powdered material and the bed is back down to its normal level 40, valve 48 is opened, allowing collector 19 to draw off the stray powdered material in the space between the core and the normal bed level. The upper enclosure is now raised and the coated core removed.

Fluidized bed 70 is replenished from bed 20 during the actual coating cycle while valve 49 is closed. A stream of gas emerging from end 56 of tube 25 drives fluidized material from bed 20 into bed 70 by way of tube 24 until it reaches level 71. Any excess falls by gravity back into bed 20 so that level 71 is automatically maintained. The apparatus is now ready for the next core and a repeat of the process steps outlined above. During the time that coating is progressing, the powdered material collected in collector 19 is fed to bed 20. Make-up material is added separately directly into bed 20 as required before the powder level drops to 56.

Preferably, the sequence of events taking place during the process of coating a core will be controlled automatically by means of a programme controller of some sort. Once the core has been loaded in the apparatus, the controller takes over control of the apparatus. It begins by lowering enclosure 13 and then takes the apparatus through the seri s of coating steps outlined above, finishing with enclosure 13 again in its raised position.

Figur 4 illustrates a core which has been coated according to the invention. It is to be noted that the bore

and the peripheral surfaces of the core have not been coated, nor have the teeth at the slot openings. Only the slot walls and the ends of the core have been coated, except for two narrow strips at each end of the core near the bore and periphery respectively. The areas coated are those which must be insulated from the conductors that will occupy the slots, that is, only those areas where grounding might occur.

The process of this invention offers a number of advantages over the conventional processes presently known to the inventor. Of these advantages, the following are considered to be the most important:

1. A minimal amount of the powdered material is used to coat a core with ground insulation;
2. No cleaning of the core is necessary after coating;
3. The coating of ground insulation is uniform in consistancy, thickness and coverage on the slot surfaces;
4. Coverage of the teeth at the ends of the core is good; and
5. Most important of all the coverage at the corners where the slots end is much better than the coverage possible in the known prior art.

In regard to item (5) corner coverage up to 75% of the flat surface coverage is now possible. This is a significant improvement in the ground insulation at those points where better coverage is needed most. The corners where the slots nd are the points where the winding conductors emerge from the slots and change direction in forming the coil end turns. Hence, these are the points where the ground insulation is needed most.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A fluidized bed system for coating an article with a powdered heat diffusible material comprising a first bed for fluidizing a quantity of said powdered material to a normal level by means of an ascending stream of a diffused gas; a container for containing said fluidized material and some space above said normal level; means for supporting said article in said space; means for opening and closing said container above said normal level for inserting or removing said article; means for intermittently raising the level of the fluidized material above said article; means for blowing excess powdered material off said article following a rise of powdered material level; a source of suction connected to said container above said normal level for exhausting stray gas carried powdered material from said space; a dust collector operative in said source of suction for collecting said stray powdered material; a second bed for fluidizing another quantity of said powdered material by means of a diffused ascending stream of said gas; means for feeding powdered material from said dust collector to said second fluidized bed; and means for feeding fluidized material from said second bed to said first bed at a controll d rate.

2. A fluidized bed system for applying a coating of ground insulation to a stator core for a dynamoelectric machine comprising a first bed for fluidizing a powdered heat diffusible insulating material to a normal level by means of an ascending current of a diffused gas; a first enclosure for said fluidized bed, said first enclosure being disposed vertically and having an open upper end; means adapting the upper end of said first enclosure for supporting said core above said normal level with its slots generally vertical and with its

under side in the vicinity of the teeth facing the fluidized bed; means included in said first enclosure permitting limited vertical movement of said first bed; means for raising said first bed to a fluidized level above the upper side of said core and then lowering it again to said normal fluidized level; a gas mask disposed in the bore of said core for directing currents of a gas over the bore surfaces of the teeth of said core to keep them relatively free from collecting powdered material during contact thereof with the teeth; a second enclosure adapted to fit onto said core so as to enclose the upper side thereof in the vicinity of the teeth, thereby placing it in fluid communication with the first enclosure through the slots in the core; means for separating said enclosures for inserting or removing a core; gas jet means in said second enclosure for directing gas streams onto said upper side of the core for blowing excess powder therefrom; a powdered material collector having a gas carried powder intake, a gas outlet and a powdered material collecting region; means for exhausting gas from said collector through said outlet; a first exhaust passage connecting said collector intake to said first enclosure in a region thereof above said normal level of the fluidized material; a valve in said first passage operable to close the passage during raised levels of the fluidized material; a second exhaust passage connecting said collector intake to said second enclosure; a second bed for fluidizing said powdered material by means of a diffused ascending current of said gas; means for feeding powdered material from said collecting region of the collector to said second fluidized bed; and means for feeding fluidized material from said second bed to said first bed at a controlled rate.

3. The system of claim 2 wherein said means for

feeding fluidized material from said second bed to said first bed comprises an intermediate fluidized bed located inside the enclosure for said second bed above the fluid level thereof and having an open top; a fluid flow passage connecting said intermediate bed to said first bed; a first vertically disposed tube having one end in the fluidized material in said second bed and the other end pointing into said intermediate bed through the open top thereof; second smaller tube having one end connected to a source of said gas at a pressure higher than the gas pressure in said second fluidized bed and its other end disposed in said one end of said first tube such that the gas released from the second tube flows through the first tube carrying fluidized material with it from the second bed to the intermediate bed; and a valve in said passage for controlling the flow of fluidized material from the intermediate to the first bed.

4. The system of claim 2 including means for operating said valves, said bed raising means, and said enclosure separating means in a controlled sequence.

5. The system of claim 2, 3 or 4 wherein said means for feeding powdered material from said collector to said second fluidized bed comprises means for supporting the collector above the bed; a duct connecting the lower portion of said collecting region of the collector to the top of said second bed; and a one-way flow valve in the duct, allowing powdered material to flow from the collector to the bed at a controlled rate without allowing gas to enter the collector via the duct.

6. The system of claim 1, 2 or 3 wherein said gas is air.

7. The system of claim 2 wh rein means is provided for ooling the components coming into contact with the stator core.

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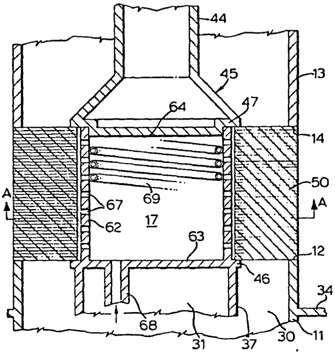

FIG. 2

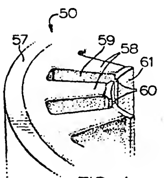

FIG. 4

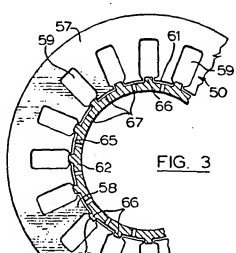

FIG. 3

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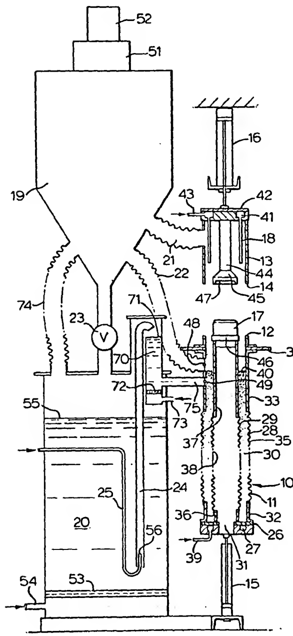

FIG. 1